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SUBJECT: Stack Discharge of UF_6 from Volatility Pilot Plant

TO: R. B. Lindauer

FROM: R. P. Milford
W. H. Carr

ABSTRACT

The possibility of UF_6 escape through the off-gas stack was examined. Since UF_6 in an off-gas stream is easily hydrolyzed by moisture in the air and the resulting UO_2F_2 is filterable, all that is necessary to prevent passage of UF_6 through the filter is the presence of sufficient moisture. Assuming a loss of 4.5 kg UF_6 in one minute from the cold trap and a maximum rate of 1.5 kg UF_6/min entering the cell off-gas duct, sufficient moisture for complete hydrolysis would be present in the atmosphere at any time the dew point is as high as $-10^{o}F$ and special provisions for addition of moisture would be unnecessary.

NOTICE

1.0 INTRODUCTION

As a portion of the preliminary study for the preparation of a formal hazards report on the Volatility Pilot Plant, a study was made of the possibility of releasing UF_6 through the off-gas stack. Moisture in air reacts almost immediately with gaseous UF_6 forming UO_2F_2 which is a solid capable of being filtered ($UF_6 + 2H_2O \longrightarrow UO_2F_2 + 4HF$). Thus, contact of the UF_6 in the gas stream with sufficient moisture prior to reaching a filter will insure retention of the uranium on the filter rather than allowing its escape up the stack. If there is sufficient moisture in the atmosphere, there is no possibility of stack discharge of UF_6; if there is not sufficient moisture, then provision must be made for addition of moisture, such as by water scrubbing of, or steam discharge into the off-gas stream.

2.0 CALCULATIONS AND RESULTS

2.1 Assumptions

a. Release into the cell of 4.5 kg UF_6 in one minute by rupture of a hot cold trap at the completion of a series of runs.

b. At least 30% of theoretical dilution in the cell, which has a volume in excess of 10,000 ft^3. Since rated off-gas flow from the cell is 1,000 cfm, these two assumptions result in a maximum rate of discharge into the off-gas duct of 1.5 kg UF_6/min.

c. A 10-fold dilution in the off-gas duct. Rated flow in the duct is 20,000 cfm and rated flow from Cell 2 is 1,000 cfm which would be a dilution factor of 20. Assuming a factor of 10 appears to allow adequate margin for high flow from Cell 2 and low total flow in the duct. These three assumptions then result in a maximum UF_6 concentration of 0.15 kg UF_6/1,000 ft^3 of air in the duct.

d. Reaction rate sufficient for completion before reaching the filters.

e. Cell exit air temperature - 40°F min.
95°F max.

2.2 Climatological Data

The dewpoint temperature of air is a direct indication of the absolute moisture content of the air. Lowest dewpoints occur during extreme cold clear periods in the winter. Conversely, highest dewpoints, or absolute humidities, occur during rainy periods in hot weather. F. C. McCullough has a file of monthly Climatological Data for the Knoxville station of the U. S. Weather Bureau, as well as several annual summaries. W. M Culkowski of the AEC/Weather Bureau office was also contacted.

The lowest temperature for the eighty years of the Knoxville Weather Bureau records was -16°F in 1902. A dewpoint temperature of about -20°F might be expected at this dry bulb temperature. This low a temperature occurs so seldom that more recent weather data was examined as shown in Table 1. Temperature data from (1) an unusually cold spell which occurred in February 1958, (2) a typical winter day in January 1959, (3) a warm rainy period in June 1959, and (4) a dry period in September 1959 are presented.

Mr. Culkowski advised that the normal local low temperature distribution is as follows:

Time at, or less than 20°F = 1%/yr
Time at, or less than 29°F = 5%/yr
Time at, or less than 34°F =10%/yr

In this temperature range, dewpoints seem to run from 0 to 20°F below the dry bulb temperature reading.

Based on all these factors, low and high dewpoints of -10 and 74°F, respectively, were chosen. The air was assumed to be leaving the cells at 40°F in cold weather and at 95°F during the hot periods.

2.3 Results

The weight of UF_6 equivalent to the water in 1000 cu ft of air at various dewpoints is presented in Table 2. Also included are the dry bulb temperatures used in the calculations. This information is plotted in Fig. 1.

Table 2

Temperatures, °F		Wt of UF_6
Dew Point	Dry Bulb	kg
-10	40	0.163
40	70	1.71
74	95	5.6

A calculation was made to determine the quantities of UF_6 which could be vaporized in 1000 cu ft of air at 40 and 95 °F. These values are shown in Table 3 along with the UF_6 vapor pressures used in the calculations. Although the rate of sublimation is unknown, 1000 cu ft of air can hold much more UF_6 as vapor than is available in the cold traps if vapor pressure of solid UF_6 is the only consideration.

Table 3

Temperature °F	UF_6 Vapor Pressure psia	UF_6 Vapor kg
40	0.48	14.8
95	4.4	163

Table 1

Date	Time	Dry Bulb °F	Dew Pt., °F	Humidity: Grains H2O/lb dry air	Humidity: lb H2O / lb dry air
2/17/59	0000	6	-2	5	0.00071
	0200	4	-3		
	0400	3	-3		
	0600	1	-5	4.2	0.0006
	0800	-2	-7		
	1000	2	-5		
	12	5	-5		
	14	10	-10	3.2	0.00046
	16	13	-5		
	18	15	-4		
	20	11	-8		
	22	7	-5		
2/18/59	0000	5	-5		
	0200	4	-6		
	0400	3	-5		
	0600	3	-5		
	0800	1	-5		
	1000	7	-5		
	1200	12	-1		
	1400	17	0	5.3	0.00076
1/1/59	0700	45	44	42.6	0.0061
1/2/59	0700	34	32		
1/3/59	0700	30	27		
1/4/59	0700	38	31	25.3	0.00362
1/5/59	0700	7	-4		
1/6/59	0700	10	1		
1/7/59	0700	21	14		
1/8/59	0700	36	36		
1/9/59	0700	22	16		
1/10/59	0700	21	15	11.7	0.00167
1/11/59	0700	17	13		
1/12/59	0700	24	18		
1/13/59	0700	44	41		
1/14/59	0700	52	46		
1/15/59	0700	52	42		
1/16/59	0700	25	20	15	0.00214
1/17/59	0700	10	5		
1/18/59	0700	11	6		
1/19/59	0700	21	16		
1/20/59	0700	35	33		
1/21/59	0700	65	54		

Date	Time	Dry Bulb °F	Dew Pt., °F	Humidity: Grains H_2O/lb dry air	Humidity: $\frac{\text{lb } H_2O}{\text{lb dry air}}$
6/24/59	0800	68	67	100	0.0143
6/29/59	0100	80	73	123	0.0176
	0700	76	69		
	1200	89	72		
	1800	95	69		
	2300	83	73		
6/30/59	0000	81	74	127	0.01815
	0600	73	71		
	1200	91	69		
	1600	95	65	92	0.01315
	1800	94	64		
	2200	85	72		
	Dry spell in Sept.				
9/19/59	0000	62	52		
	0600	57	47*	47	0.00672
	1200	75	55		
	1800	75	61		

*Lowest DP in Sept. 1959

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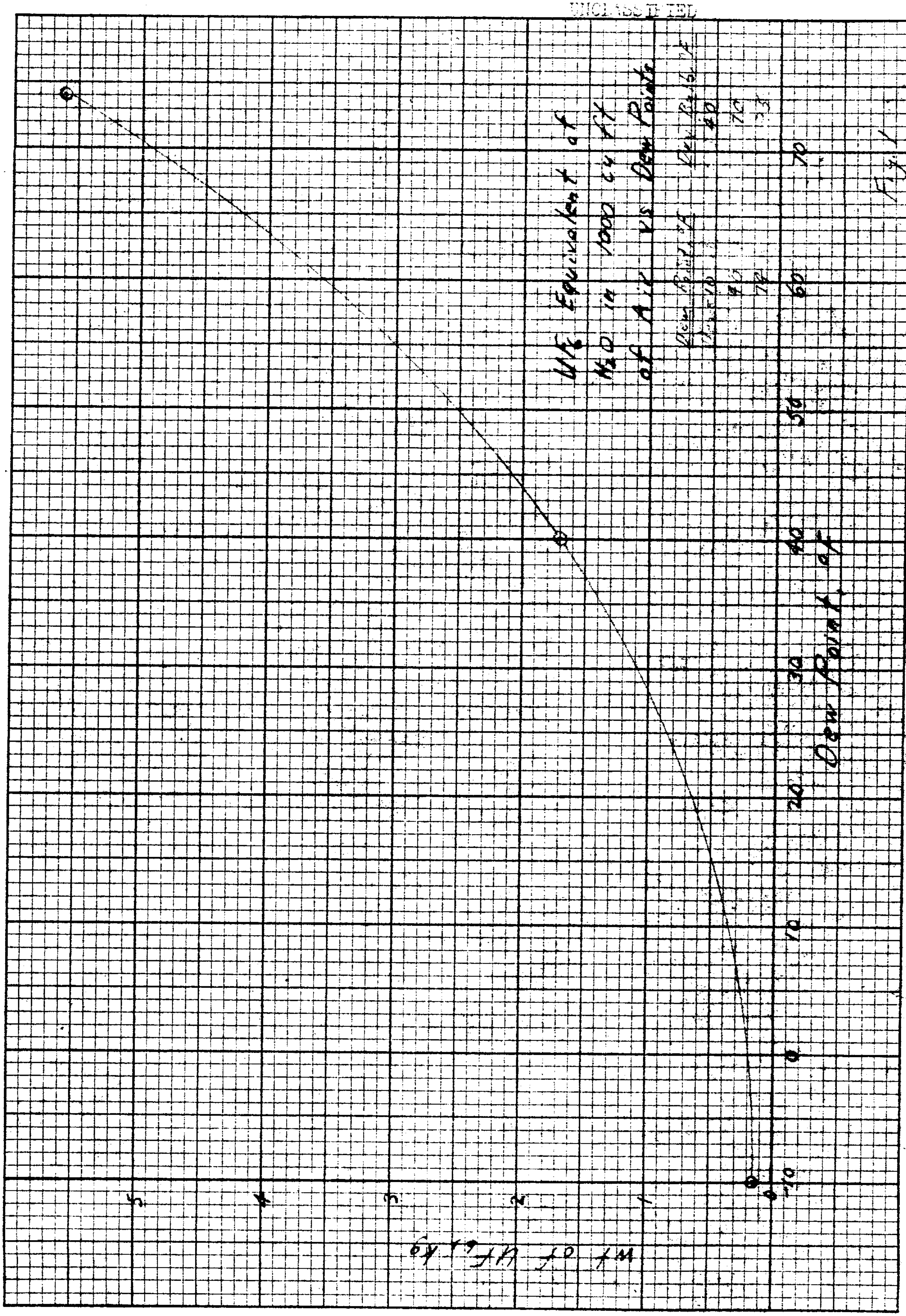

These calculations show that, under the assumptions listed, there will be enough moisture in the air to react with all the UF_6 involved in one complete processing program. However, they also show that during cold dry periods there is so little moisture that the assumptions are critical.

4.0 Conclusion

Provision for addition of moisture to the off-gas stream is unnecessary.

R. P. Milford
R. P. Milford
Process Design Section
Chemical Technology Division

W. H. Carr
W. H. Carr
Pilot Plant Section
Chemical Technology Division

5.0 Appendix - Calculations

12/17/59 R[illegible]M

Find weight of UF_6 which will react with H_2O in 1000 cu ft of air at 40°F, -10°F dew point.

$$\text{wt of } UF_6\text{, kg} = \frac{\frac{\text{lbs } H_2O}{\text{lb dry air}} \cdot 1000 \cdot UF_6}{\frac{\text{cu ft}}{\text{lb dry air}} \cdot 2H_2O \cdot \frac{\text{lbs}}{\text{kg}}}$$

$$\frac{\text{lb } H_2O}{\text{lb dry air}} = 0.00046 = H$$

$$\frac{\text{cu ft}}{\text{lb dry air}} = \left(\frac{359}{29}\right)\left(\frac{t+460}{492}\right) + \left(\frac{359\,H}{18}\right)\left(\frac{t+460}{492}\right)$$

$$= (0.730t + 335.7)\left(\frac{1}{29} + \frac{H}{18}\right)$$

$$= [(0.730)(40) + 335.7]\left(0.0345 + \frac{0.00046}{18}\right)$$

$$= (29.20 + 335.7)(0.0345 + 0.0000256)$$

$$= (364.9)(0.0345)$$

$$= \underline{12.59} \text{ cu ft/lb}$$

$$\text{wt } UF_6 = \frac{0.00046\,(1000)(352)}{12.59\,(36)\,(2.2)}$$

$$= \underline{0.163} \text{ kg}$$

$$\begin{array}{r} 0.73 \\ \underline{40} \\ 29.20 \end{array}$$

$$\begin{array}{r} 29.20 \\ \underline{335.7} \\ 364.9 \end{array}$$

UF_6

$$\begin{array}{lr} U: & 238 \\ 6F: & \underline{114} \\ & 352 \end{array}$$

Find weight of UF_6 which will react with H_2O in 1000 cu ft of air at 95°F with a dew point of 74°F.

$H = 0.01815$ lb H_2O/lb dry air

$$\frac{\text{cu ft}}{\text{lb dry air}} = (0.730(95) + 335.7)\left(0.0345 + \frac{0.01815}{18}\right)$$

$$= (69.4 + 335.7)(0.0345 + 0.001)$$

$$= (405.1)(0.0355)$$

$$= \underline{14.4} \text{ cu ft/lb}$$

69.4
335.7
405.1

$$\text{wt } UF_6 = \frac{(0.01815)(1000)(352)}{(14.4)(36)(2.2)}$$

$$= \underline{5.6} \text{ kg}$$

Find quantity of UF_6 possible to exist as a vapor in 1000 cu ft of dry air at 40°F and 95°F.

$$\frac{W_v}{W_a} = \left(\frac{p_v}{P - p_v}\right)\left(\frac{M_v}{M_a}\right)$$

p_v = vapor pressure of UF_6 at temp

M_v = 352 (Mw of UF_6)

P = 14.7 psia

M_a = 29 (Mol wt of air)

For 40°F p_v = 0.48 psia

For 95°F p_v = 4.4 psia

14.70
0.48
14.22

14.70
4.4
10.3

For 40°F $W_v/W_a = \left(\frac{0.48}{14.7 - 0.48}\right)\frac{352}{29}$

$= \left(\frac{0.48}{14.22}\right)(12.1) = 0.41 \frac{\text{lb } UF_6}{\text{lb air}}$

For 95°F $W_v/W_a = \frac{4.4}{10.3}(12.1) = 5.16 \frac{\text{lb } UF_6}{\text{lb air}}$

$$\frac{\text{wt of } UF_6}{1000 \text{ cu ft air}} = \frac{\dfrac{\text{lb } UF_6}{\text{lb air}} \quad 1000}{\dfrac{\text{cu ft}}{\text{lb air}}}$$

For 40°F

$$\text{wt } UF_6 = \frac{(0.41)(1000)}{12.59}$$

$$= 32.6 \text{ lbs } UF_6$$

$$= \underline{14.8} \text{ kg } UF_6$$

For 95°F

$$\text{wt } UF_6 = \frac{(5.16)(1000)}{14.4\ (2.2)}$$

$$= \underline{163} \text{ kg } UF_6$$

Since only 4.5 kg of UF_6 are involved, entire quantity will be vaporized at either 40 or 95°F.

RPM 12/18/59

Find weight of UF_6 which will react with H_2O in 1000 cu ft of air at 70°F with a dew point of 40°F.

H = 0.0052 lb H_2O/lb dry air

0.730
70
51.10

$$\frac{\text{cu ft}}{\text{lb dry air}} = [0.730)(70) + 335.7](0.0345 + \frac{0.0052}{18})$$

51.1
335.7
386.8

$$= (51.1 + 335.7)(0.0345 + 0.000289)$$

$$= (386.8)(0.0348)$$

$$= \underline{13.5} \ \frac{\text{cu ft}}{\text{lb dry air}}$$

$\frac{-3+3+2}{1+1}$

$$\text{wt } UF_6 = \frac{(0.0052)(1000)(352)}{(13.5)(36)(2.2)}$$

$$= \underline{1.71} \text{ kg}$$

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